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AUTHOR	Garza, Javier; Havlak, Karl; Riggs, Elisabeth; White, Peter
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ABSTRACT

Currently, in Texas public schools, there is a shortage of teachers holding secondary mathematics teaching certification. Many teachers have limited access to professional development opportunities due to occupational commitments, geographic proximity, family obligations, or inconvenience of transportation. However, with the incorporation of technology in Texas school systems, these teachers would have the means to participate in a computer-based mathematics course designed to help them prepare for the certification exams. In this paper, the authors discuss the development of a computer-based College Algebra course and related issues such as generic (text-independent) content, Web-based delivery formats and web publishing software. (Author)

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Development of a Computer-Based College Algebra Course

by

Dr. Javier Garza (garza@tarleton.edu), Dr. Karl Havlak (havlak@tarleton.edu),
Ms. Elisabeth Riggs (eriggs@tarleton.edu), and Dr. Peter White (white@tarleton.edu)

Tarleton State University
Stephenville, TX 76402

Abstract. Currently, in Texas public schools, there is a shortage of teachers holding secondary mathematics teaching certification. Many teachers have limited access to professional development opportunities due to occupational commitments, geographic proximity, family obligations, or inconvenience of transportation. However, with the incorporation of technology in Texas school systems, these teachers would have the means to participate in a computer-based mathematics course designed to help prepare them for the certification exams. In this paper, the authors discuss the development of a computer-based College Algebra course and related issues such as generic (text-independent) content, web-based delivery formats and web publishing software.

Introduction

Accountability systems are becoming more and more prevalent in Texas public education. The media is constantly reporting test scores and performance comparisons among various groups of students. Just as in industry, low-performing segments of education are being targeted in hopes of improving student outcomes.

One particular set of results that seems particularly disturbing is the data on the Algebra I End-of-Course Exam that is currently being utilized in Texas public schools. The percentage of students not in special education passing the exam increased from 39% in Spring 1998 to 47% in Spring 1999 [TEA]. With less than half the students passing the exam, what component of the system is breaking down in the cycle of education in the Algebra I course? More importantly, what can be done about it?

There are many variables involved in such a complex situation as teaching algebra to public school students and then assessing that knowledge on an end-of-course exam. The test developers follow a very careful process to develop a test in alignment with the algebra curriculum and educators from school districts across the state review potential test items on the test before those items are actually put on the assessment instrument. For further information on the development of the End-of-Course Algebra I exam and other tests, see the Texas Education Agency's website at http://www.tea.state.tx.us/student.assessment/develop.htm. Since this test is being carefully constructed and reviewed, educators should be very concerned about students who are not learning the material. More importantly, this concern should be addressed by investigating possible causes for the low performance of Algebra I students. According to former Texas Commissioner of Education, Mike Moses, "one of the contributing factors may be difficulty in obtaining qualified, certified teachers for Algebra" [M]

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J. Garza

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The Project

In hopes of improving the preparation of public school mathematics teachers, mathematics faculty at Tarleton State University embarked on a project to develop an computer-based mathematics program that would, as its primary purpose, help public school teachers obtain certification in mathematics. The developers received financial support for this project from West Texas A&M University (as part of a grant that was received for educator preparation) and from Tarleton State University.

The Primary Audience: Non-Certified Teachers

In recent years, school districts across the country have had to scramble to compete for qualified teachers to fill vacant positions. In particular, teachers holding certification in critical need areas (mathematics, science, special education, and bilingual education) have been in high demand. Table 1 provides an indication as to the scope of the problem in Texas public schools regarding the shortage of teachers holding the secondary mathematics certificate. Jimmy McCoy, Head of the Department of Mathematics and Physics at Tarleton State University (TSU), suggested the development of an computer-based mathematics program designed to help public school teachers obtain the secondary mathematics teaching certificate. In particular, he suggested that the program provide preparation to those public school teachers that are certified to teach in an area other than mathematics but, due to the shortage of mathematics-certified teachers, are called upon to teach mathematics. Currently, the State of Texas allows a person holding teacher certification in one area to add secondary mathematics certification areas by passing the Examination for the Certification of Educators in Texas (EXCET) in mathematics.

		Middle/Junior High (7-8)					Secondary (9-12)			
		Certified		Non-Certified			Certified		Non-Certified	
	Total	N	%	N	%	Total	N	%	N	%
1996-97	6170	4260	69.0	1910	31.0	11589	9487	81.9	2102	18.1
1997-98	6500	4465	68.7	2035	31.3	12154	9919	81.6	2235	18.6

Table 1. Texas Public School Teachers of Mathematics Holding Target Certificate, by Grade Level and School Year. Note: Some teachers hold the Elementary Certificate to teach Grades 1-8 and can legally be assigned to teach 8th-grade mathematics courses. That teacher would be identified as "not holding the target certificate" because the target certificate for a grades 7-8 mathematics teacher is the secondary mathematics certificate. [S1]

The objective of this project is to reduce the impact of non-certified mathematics teachers on the student population by assisting public school teachers in preparing for the EXCET and obtaining the appropriate certification. Such an educator preparation program would ideally be established for delivery over distance to optimize access to the program. The typical public school teacher would only have time on weekends, school nights, and summers to spend studying the course material.

Though it is the greater hope that the courses developed for this computer-based program will bring about change in the preparation of public school mathematics teachers, there is a

significant byproduct for the two courses. Since College Algebra and Precalculus are staples of most mathematics programs across the nation, the internet delivery of this content will provide access for the following groups of students:

- college students seeking credit for College Algebra and/or Precalculus, and
- high school students seeking dual credit for either course

The delivery over distance allows for students that have limited access to such courses due to occupational commitments, geographic proximity, or inconvenience of transportation.

Course Content

In choosing two course areas for development of the initial components of the computer-based program, the developers considered the emphasis placed upon algebra and precalculus concepts in the test framework of the EXCET and decided to develop a College Algebra course and a Precalculus (with Analytic Geometry and Trigonometry) course. Table 2 below outlines the test framework for the EXCET in Secondary Mathematics. The number of competencies within each domain is directly correlated to the emphasis placed on each domain in the examination.

Test Framework for Secondary Mathematics EXCET	
Domain	**No. of Competencies**
Mathematical Foundation	5
Algebra	12
Geometry	9
Trigonometry, Analytic Geometry, Elementary Analysis, and Calculus	9
Probability, Statistics, and Discrete Mathematics	6

Table 2. Domains and Competencies for Secondary Mathematics EXCET.
Source: *Preparation Manual for the EXCET (Mathematics 17)*, State Board for Educator Certification. [S2]

The College Algebra course will be offered as a Post-Baccalaureate course targeted to public school teachers for the first time in spring 2000. It is the intent to offer the Precalculus course similarly in fall 2000. The remainder of this paper will focus on lessons learned while developing the College Algebra course. The Precalculus course is being developed currently.

One of the authors' goals in developing the College Algebra course was to produce course content that, to a large extent, was textbook-independent. Each section in the computer-based College Algebra course consists of an introduction and explanation of the section topic followed by a series of examples. This course is designed as a multimedia tool with which the student can interact and is intended to replace the lecture part of a college algebra course. No problem sets are specifically assigned in the content part of this course. It is left up to the instructor to develop and assign homework problems as a complement to the computer material. The instructor is encouraged to use web forms for online homework and quizzes.

The content of the College Algebra computer-based course is modeled after the 3-credit-hour semester course taught in the Department of Mathematics and Physics at Tarleton State University. Mathematical concepts are arranged in seven chapters with the primary emphasis being the study of functions. The seven chapters are as follows:

- Fundamental Concepts (optional)
- Linear Functions
- Quadratic Functions
- Polynomial Functions
- Rational Functions
- Radical Functions
- Exponential and Logarithmic Functions

In each chapter the emphasis is placed on algebraic manipulation, graphical analysis and the application of the functions. The student is able to read about the concepts, hear short sound clips from the developers, and view animations of the graphs of the basic algebraic functions.

Overview of Product

Once the content was determined, the developers had to design a layout for the content that would be both appealing to the student and user-friendly. Furthermore, several course delivery issues had to be addressed early in the development process. This section will describe some of these issues including the layout or interface, the degree of student interactivity that could be achieved, as well as other decisions about the delivery of course content.

Delivery

One goal of this project was to develop a system for delivering the content of a mathematics course, in this case College Algebra, to a diverse off-campus audience. Two main concerns with the delivery of an computer-based course are accessibility and user-friendliness. The developers decided to use HTML for the content and ASF format for the sound and video so that the course could be distributed over the internet. However, because of current bandwidth limitations, it was decided to also distribute the product on CD's for the initial offering of the course. For ease of use, the developers used standard web-page layouts and tried to minimize the need for technical expertise on the part of the student.

Several formats were considered such as *Microsoft PowerPoint*, *Scientific Notebook* and *Maple*. The developers decided to use an HTML format for delivery of the content because HTML is versatile enough to handle graphics, sound and video. HTML requires no proprietary software to view the content and can have a high level of interactivity. This decision was based on the observations listed in Table 3.

Once the decision was made to use HTML as the format, the developers noted that there were no HTML editors designed for the publication of mathematical content. There are several software packages that convert from their native format to HTML, but each package considered seemed to lack at least one crucial component. Thus, a combination of *Maple* and *Microsoft Word* was used to generate the HTML code. The HTML files were then edited using *Netscape Composer*.

Layout

The developers decided to use a system of frames as the primary layout for the course content. Most of the space on the browser page is used for the content. An interactive index is

provided along the left side of the window as well as a small window for the display and control of animations, video, and sound (see Figure 1).

Each section begins with an introductory video clip featuring the author of that section. The author for each section has also recorded short sound clips that the student may listen to while working through the course content. The sound clips are indicated by a headphone icon, while animations and video clips use a film-media icon (see Figure 1). Having control of the audio and video clips allows the student, by a click of the mouse, supplement the main content and achieve some level of interactivity with the material.

Within this layout of frames, the student can move from section to section using hyperlinks and can view animated graphics, sound and video clips while the course content is still on the screen. The developers felt that this layout was superior to a pop-up window approach considering the target audience. This method for displaying information does not require the user to close a window when finished viewing the media file or to move the window around to see the course content. The disadvantage of this system is that the video and index frames take up space even when not being used.

Figure 1. Frames Layout.

Software Packages Considered

The developers of the computer-based College Algebra course considered a number of different software packages for content creation before settling on HTML generated through

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Maple V and *Microsoft Word*. The criteria used by the developers in choosing the software package were as follows:

1. Appealing to students technologically and aesthetically -- not requiring students to acquire numerous plug-ins or to learn a software package; readable and professional in appearance
2. Easy for developers to use in creating content -- mathematics and text easily integrated; mathematical graphics easily inserted; sound and video feasibly incorporated
3. Exportable to HTML or MATHML -- browsable end product; desired a format that supports the viewing of mathematics

In Table 3 below are comments on how several of the software packages under consideration fared in meeting the above criteria. The comments are numbered as they relate to the corresponding criterion above.

Software Package	**Comments**
Microsoft Word - word processing package.	1. Mathematical content is very professional in appearance. Equation color is black by default; each equation must be altered individually if another color is desired. 2. Developers were familiar with this software package and found it appropriate for the course content production. 3. *Microsoft Word* documents are exportable to HTML but some of the formatting is lost in the conversion. *Microsoft Word* equations are not exportable in a usable format to MATHML. These limitations were a major setback in the view of the developers.
Microsoft PowerPoint - presentation graphics package.	1. Creates very professional documents. Can easily incorporate animations, sounds, and other special effects for capturing the students' attention. Not clear whether the end product has to be viewed in *Microsoft PowerPoint*, which would require students to have that software package and know how to use it. 2. Content production slow because of all the special effect capabilities. Allows for narration of a presentation and easy insertion of video clips, but there were synchronization problems in the final product and the size of the files was very inhibitive. 3. Equations can be easily inserted using the equation editor, but these equations are not exportable to MATHML. Is exportable to HTML, but the results obtained by the developers were unacceptable.

Latex - scientific word processor.	1. Produces very professional documents. 2. Not all the developers were extensively familiar with *Latex*. 3. Exportable to HTML and MATHML. The resulting document from the HTML conversion was of low quality, and MATHML was not well developed at time of consideration.
TechExplorer - *Latex* viewer.	1. Students would have to purchase the software. 2. Not all the developers were extensively familiar with *Latex*. 3. Exportable to HTML and MATHML. MATHML was not well developed at time of consideration.
Maple - computer algebra system.	1. Can create documents with formatting and color for emphasis. 2. Developers very familiar with *Maple*. Mathematical graphs and expressions easily incorporated. 3. Exportable to HTML and is expected to be exportable to MATHML as it becomes more fully developed.
Scientific Notebook - scientific word processor with computer algebra system capabilities.	1. Plug-ins required. Can create very interactive pages, but students would have to learn to use an interface. 2. Only one of the developers had extensive knowledge of the software package. 3. Exportable to HTML and is expected to be exportable to MATHML as it becomes more fully developed. Technical difficulties arose with certain hardware configurations at the time the software was being considered.

Table 3. Comparisons of Software Packages.

Many of the problems mentioned above could almost certainly have been overcome for the different software packages; the developers are simply trying to represent the difficulties that were encountered as the field of possibilities was narrowed. Some of the perceived difficulties with the given software packages stem from a lack of familiarity with the software package.

Technical Description

The computer-based College Algebra course was developed primarily with the aid of three software packages: *Maple V Release* 5, *Netscape Composer* 4.51, and *Adobe Premiere* 5.1. *Maple* and *Netscape Composer* were used for content creation and HTML editing while *Premiere* was used for sound and video editing. Other software packages, including *Microsoft Word* and *Microsoft Photo Editor,* were utilized to a lesser degree for equation and GIF image editing.

Maple

Maple is a comprehensive computer algebra system for performing many mathematical computations. The capability of computer algebra systems to perform symbolic manipulations and produce high quality mathematical graphics has had a profound impact on the way many universities teach mathematics(see e.g., [L], [SD], [R]). Having used *Maple* in teaching courses at TSU, the developers had a fairly strong knowledge of its capabilities when the creation of the computer-based College Algebra course began. *Maple* has several strengths that helped the developers to decide upon its use, but the developers did discover several difficulties in utilizing the software package.

Content Production. *Maple* has the utility of providing a means for editing mathematical content as well as providing word processing capabilities. Text and mathematical content can be incorporated rather easily into a *Maple* document each with its own formatting. The user is allowed most of the standard formatting options such as font styles and sizes; bold, italics, and underline; centering and justifying; and color, but the user also has a ready interface for entering mathematical expressions, equations, and graphs. Though *Maple* allowed for ease in incorporating mathematics and text into a single document, the process was not seamless.

- **Formatting Problems:** As the content for the different sections of the course was generated, it was noted that format changes were inexplicably taking place. For example, italicized text would change to bold. In other instances, colored text and equations would change to black. The format changes were restricted to the worksheet that was open, and it was noted that they seemed to occur after using cut and paste. To avoid this problem the developers took several approaches: 1) the developers did not use cut and paste freely (which was somewhat inhibitive); 2) the developers inserted all formatting only after all the content was entered; and 3) the developers completed the formatting outside of the *Maple* software package. These steps did prevent the formatting problems, but they also countered some of the motivation behind using *Maple* for inputting content.
- **Mathematical Formatting Problems:**
  - *Maple's* mathematical content has an established format that cannot be altered, and the default format was often deemed unacceptable by the developers (see Table 4). To circumvent this problem, the developers chose to use the *Equation Editor* in *Microsoft Word*. The *Microsoft Word* equations were easily formatted and pasted into the *Maple* worksheet where needed. This solution did require the use of an additional software package to generate the content, which was a situation the developers had hoped to avoid.

Maple output	Acceptable output
$x^{\left(\frac{1}{2}\right)}$	$x^{\frac{1}{2}}$
$\log_{\frac{1}{2}}\left(\frac{x^2+1}{x^2}\right)$	$\log_{\frac{1}{2}}\left(\frac{x^2+1}{x^2}\right)$

Table 4. Example of Mathematical Formatting Problems Encountered in *Maple*.

- In some instances, the mathematical output initially appeared as the developers intended, but, after exiting and reopening the worksheet, the output was altered by *Maple* (see Table 5). If such an alteration was noted, the developers converted the desired expression to HTML in a separate worksheet and pasted it into the final HTML page where it was needed. It seemed that this altering of expressions occurred when some of the more complicated mathematical expressions were entered.

Expression as intended	Expression after exiting and reopening
$\dfrac{\left(\frac{1}{x}-\frac{1}{x-1}\right)\frac{x+1}{x+1}}{\left(\frac{2}{x}+\frac{3}{x-1}\right)\frac{x+1}{x+1}}$	$\dfrac{\left(\frac{1}{x}-\frac{1}{x-1}\right)(x+1)}{(x+1)\dfrac{\left(\frac{2}{x}+\frac{3}{x-1}\right)(x+1)}{x+1}}$

Table 5. Alterations of Mathematical Output By *Maple* When Exiting and Reopening Worksheet.

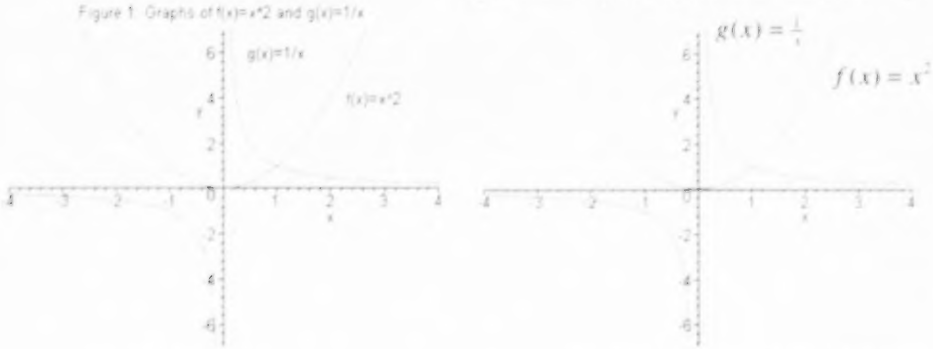
- *Maple* does not allow some of the mathematical formatting that is pedagogically useful in a College Algebra course. For example, mathematical input is often entered with extra parentheses for emphasis. *Maple* tends to ignore excess parentheses, which can disrupt the exposition of the material and can actually introduce confusion (see Table 6). *Microsoft Word* was used where the developers were unable to obtain acceptable results from *Maple*. Also, *Maple* only allows the input of mathematical expressions or equations; it will not allow a string of equalities to be entered. In a College Algebra course, the steps needed to solve a given problem are frequently shown using a string of equivalent mathematical statements separated by an equal sign. In *Maple*, a string of equalities has to be entered one expression at a time separated by an equal sign typed as text input. For the most part, this formatting issue was merely an annoyance, but it did require some extra HTML editing to properly align the mathematical expressions and the text equal signs.

Maple Output	Output as intended
$2\,(x+4)=2\,x+2\,4$	$2(x+4)=(2)(x)+(2)(4)$
$a\,b\,c=a\,b\,c$	$a(bc)=(ab)c$
$\dfrac{x\,(x-1)}{(x+1)\,(x-1)}$	$\dfrac{x}{x+1}\cdot\dfrac{x-1}{x-1}$

Table 6. Omission of Desired Parentheses by *Maple*.

- There are some mathematical symbols that the developers simply could not create using *Maple*. For example, the symbol ± is unavailable, and it is vital to any discussion of the quadratic formula. Again, *Microsoft Word* was used to compensate.
- One of the advantages of using *Maple* was the ability to easily incorporate graphs in the content; however, this was not done without some formatting difficulties. Problems arose in labeling the graphs and in overwriting the graph with text. *Maple* uses a text font in these situations and not a mathematics font, so keyboard symbols were used in place of mathematical symbols. For example, x^2 was used instead of x^2 and 1/x instead of $\frac{1}{x}$ (see graphs in Figure 2).

Figure 1: Graphs of $f(x) = x^2$ and $g(x) = \frac{1}{x}$



(a) *Maple* Output (b) *Maple*/*Microsoft Word* Output

Figure 2. Overlaying text and titling figures in *Maple* and using *Microsoft Word*. Graph (a) was created in *Maple* and is rather straightforward to create using *plot*, *textplot*, and *display* commands. Graph (b) was created in *Maple* and the title and text entered in *Microsoft Word*.

- Using *Microsoft Word* to create mathematical content did give rise to an additional problem. The developers chose to display mathematical content in color, and the equation editor in *Microsoft Word* does not allow for color changes. To change the color, each equation and expression created in *Microsoft Word* was opened in *Microsoft Photo Editor*. The balance was then adjusted until the color matched that selected by the developers for use in *Maple* (see [SM] for more information about changing the color of *Microsoft Word* equations). This editing procedure becomes somewhat cumbersome because the color of each equation and expression has to be adjusted individually.

Converting to HTML. The developers chose the *Maple* software package in part because of its capability of exporting mathematics and text to HTML with relative ease. The exported *Maple* worksheets were less than 50 KB in size for each section of the course. For the most part, the export was completed with the formatting specified in *Maple* intact. The mathematical expressions and equations specified in the *Maple* worksheet were converted into GIF images. The developers encountered several difficulties in this conversion.

- **GIF Images:** The GIF images were typically close to 1 KB in size and were virtual clones of the expressions and equations in *Maple*. However, two issues arose involving GIF images that the developers had to overcome.
    - *Maple* converts each expression and equation into a GIF image, so that, if an expression such as $ax^2 + bx + c$ occurs more than once in a section, each occurrence will be saved as a separate GIF image. To decrease the size of the HTML files, each occurrence of a common expression or equation has to be linked to one of the common GIF images and the remaining images deleted.
    - *Maple* includes default spacing in the GIF images that caused expressions and equations occurring in-line with the text to not conform to the specified formatting (see Figure 3). Not only do the images cause extra space to appear in the line in which they appear, they also cause space to occur between lines. To adjust the GIF images, each was opened in *Microsoft Photo Editor* and the margins chopped so the image would not cause the additional space in and between the lines. Then, for the images to appear correctly when opened, the HTML code was edited to remove the height and width tags.

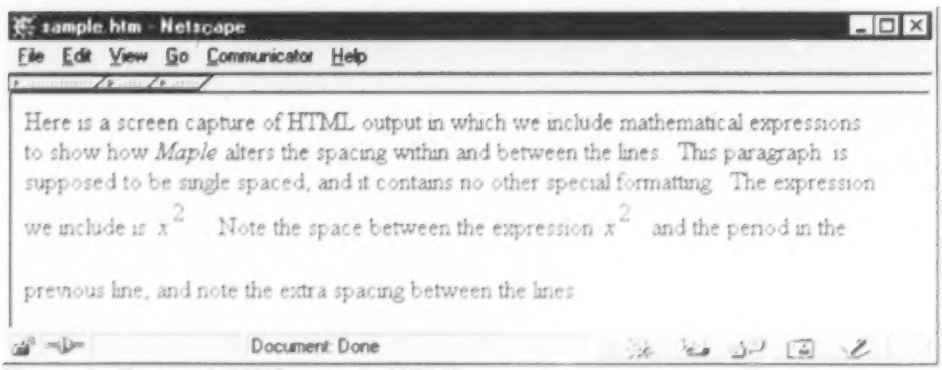

sample.htm - Netscape
File Edit View Go Communicator Help
Here is a screen capture of HTML output in which we include mathematical expressions to show how Maple alters the spacing within and between the lines. This paragraph is supposed to be single spaced, and it contains no other special formatting. The expression we include is x^2. Note the space between the expression x^2 and the period in the previous line, and note the extra spacing between the lines.
Document: Done

Figure 3. Text and GIF Images in HTML.

- **HTML Adjustments:** Once the *Maple* worksheets were exported to HTML, much of the final formatting was completed using *Netscape Composer*. Several features of the HTML files constructed by *Maple* need to be described. *Maple* creates a table of contents and frames by default. Originally, the developers felt this would expedite the process of creating an online course; however, the frames created by *Maple* did not fit the framework that the developers chose for the course. In particular, the developers wished to include a video window and additional information in the table of contents window. *Maple* also included targets and other HTML coding that the developers felt were excessive, which lengthened any process that required HTML editing.

Netscape Composer

Netscape Composer is a software package with which the developers had some experience prior to developing this course. It proved to be an efficient software package for final formatting of the HTML pages. *Netscape Composer* allowed the developers to easily incorporate

images, targets, links, lines, and tables. In addition, many word processing formatting options were available. However, *Netscape Composer* had some drawbacks that will likely influence the developers in future online course development.

- *Netscape Composer* is not set up to easily create and manage frames. The developers had to create their own frames using HTML code.
- *Netscape Composer* will not allow editing of HTML source. Such editing had to be done using an external software package like *Microsoft Notepad.*

Adobe Premiere

One of the features of the computer-based College Algebra course is the inclusion of animation, sound, and video. *Adobe Premiere* was utilized by the developers to create this multimedia portion of the course and to make it user-controlled.

- **Animations:** Animations were used by the developers to show graphs changing over various choices of parameters for pedagogical impact. Animations were created in the *Maple* software package and saved as HTML source. *Premiere* was then used to convert the animations into video clips. These clips were less than 500 KB in size, and the frames per second rate was set as low as possible (as low as 1 fps to as high as 5 fps) to keep the size of the files small.
- **Sound and Video:** *Adobe Premiere* allows for the capture of sound and video files, which can then be compressed or converted to other formats for use in an HTML file. The developers captured the sound and video files using high-quality settings: CD quality 44 kHz for sound and 30 fps, 44 kHz, 16 bit mono for video. Initially, the developers hoped that exporting the files with lower quality settings would yield files that were sufficient for use in the course. However, to maintain the desired quality, the compressed files were simply too large to be feasibly incorporated or were small but of poor quality (see Tables 7 & 8). The developers decided to convert the files to the ASF format [H].

File Type	Original Sound Clip	Compressed WAV	ASF
Size	5 MB	50 KB - 650 KB	80 KB

Table 7. Size of 30 Second Sound Clip.

File Type	Original Video Clip	Compressed AVI	ASF
Size	50 MB	1 MB - 6 MB	400 KB

Table 8. Size of 30 Second Video Clip.

Premiere offered several compression algorithms from which to choose, and it even allowed the developers to customize the specifications of the compression. The developers settled on the settings in Table 9. The ASF files proved to be much more manageable, and allowed the developers to incorporate the large number of sound and video files that are found in the course.

ASF Sound Files	Audio Format: 20 KB/s, 22 kHz (mono) Audio Codec: Microsoft Audio Codec
ASF Video Files	Audio Format: 16 KB/s, 16 kHz (mono) Audio Codec: ACELP.net Video Codec: MS-MPEG4 V3

Table 9. ASF Settings.

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